

(12) UK Patent Application (19) GB (11) 2 278 717 (13) A

(43) Date of A Publication 07.12.1994

(21) Application No 9410561.6

(22) Date of Filing 26.05.1994

(30) Priority Data

(31) 05149827

(32) 31.05.1993

(33) JP

(71) Applicant(s)

Fujitsu Limited

(Incorporated in Japan)

1015 Kamikodanaka, Nakahara-ku, Kawasaki-shi,
Kanagawa 211, Japan

(51) INT CL⁵

H01S 3/091 3/094

(52) UK CL (Edition M)

H1C CEX C35X C35Y C48Y C49Y C491 C496 C498 C643
C660 C666 C735

(56) Documents Cited

GB 2245757 A

(58) Field of Search

UK CL (Edition M) G3R RBX, H1C CBAA CBAX CEA
CEX
INT CL⁵ H01S 3/09 3/091 3/0933 3/094

(72) Inventor(s)

Daisuke Kadota

Futoshi Ogawa

Shinichirou Harasawa

(74) Agent and/or Address for Service

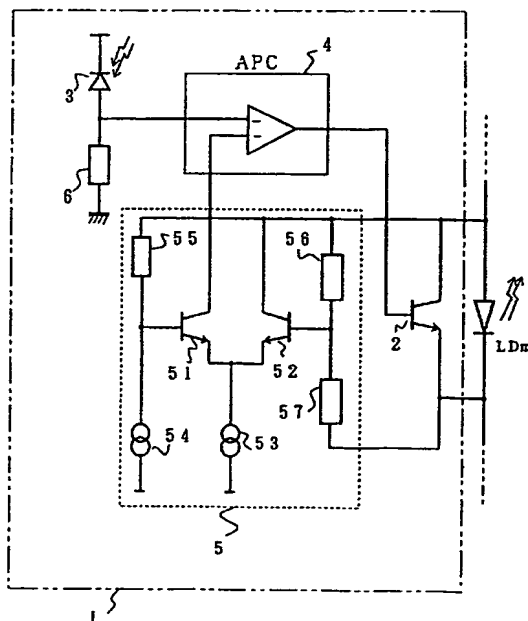
Haseltine Lake & Co

Hazlitt House, 28 Southampton Buildings,
Chancery Lane, LONDON, WC2A 1AT,
United Kingdom

(54) Driver circuit for light emitting elements

(57) A driver circuit, particularly for the light emitting elements of an optical amplifying repeater, maintains power to the remaining operational light-emitting elements LD_m when one or more of a series of light-emitting elements has a disconnection fault. The elements may be laser diodes.

The driver circuit has series-connected multiple light-emitting elements $LD_1 \sim LD_n$, connected to a constant-current power source and a corresponding emitted light power control circuit 1 for each of the light-emitting elements. Each control circuit 1 has a bypass current control element 2 connected in parallel to the corresponding light-emitting element, LD_m , a light-receiving element 3 detecting the light emitted by the associated light-emitting element LD_m , a current control circuit 4 controlling current flowing through the bypass current control element 2 in accordance with the light receipt level and a voltage detecting circuit 5 which increases the current flowing to the bypass current control element 2 when the voltage between the terminals of the corresponding light-emitting element LD_m reaches or exceeds a fixed voltage value.

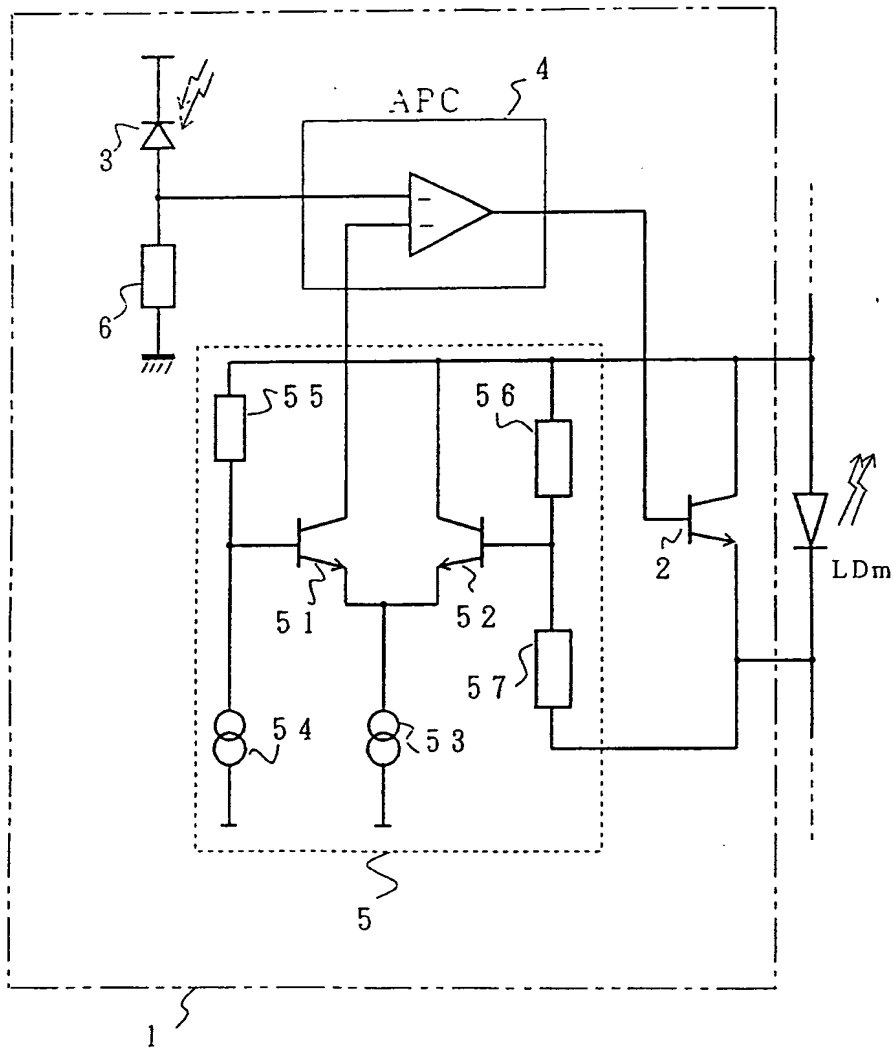


BEST AVAILABLE COPY

GB 2278717 A

1/1

FIG. 1



2/7

FIG. 2

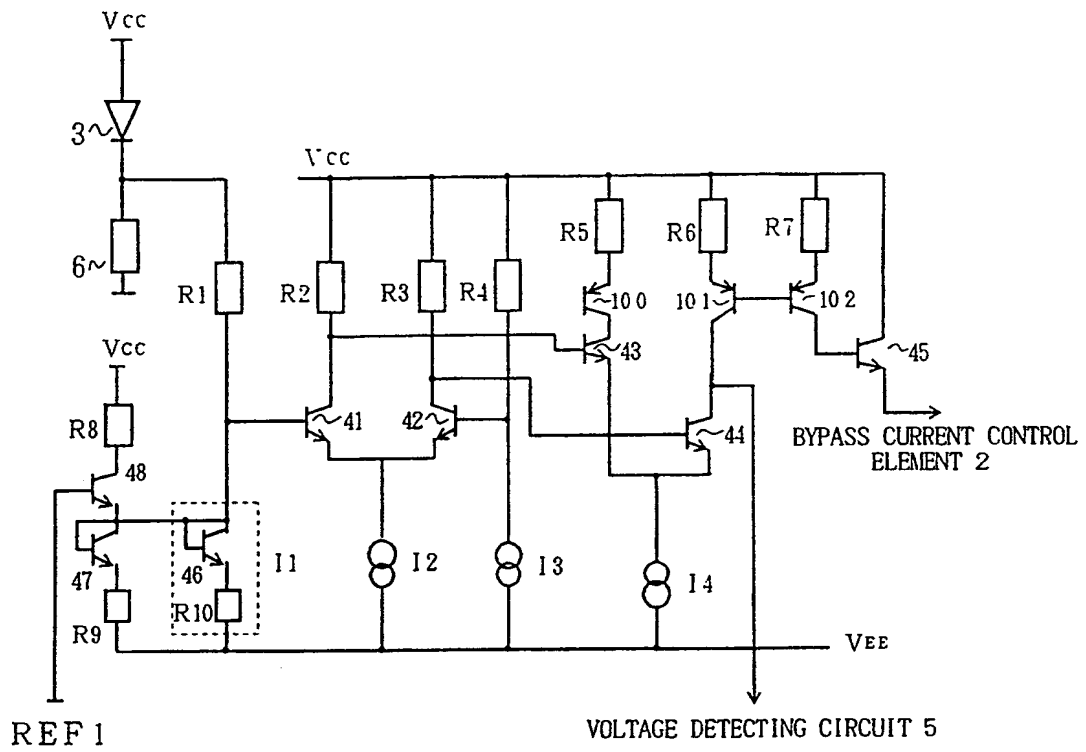
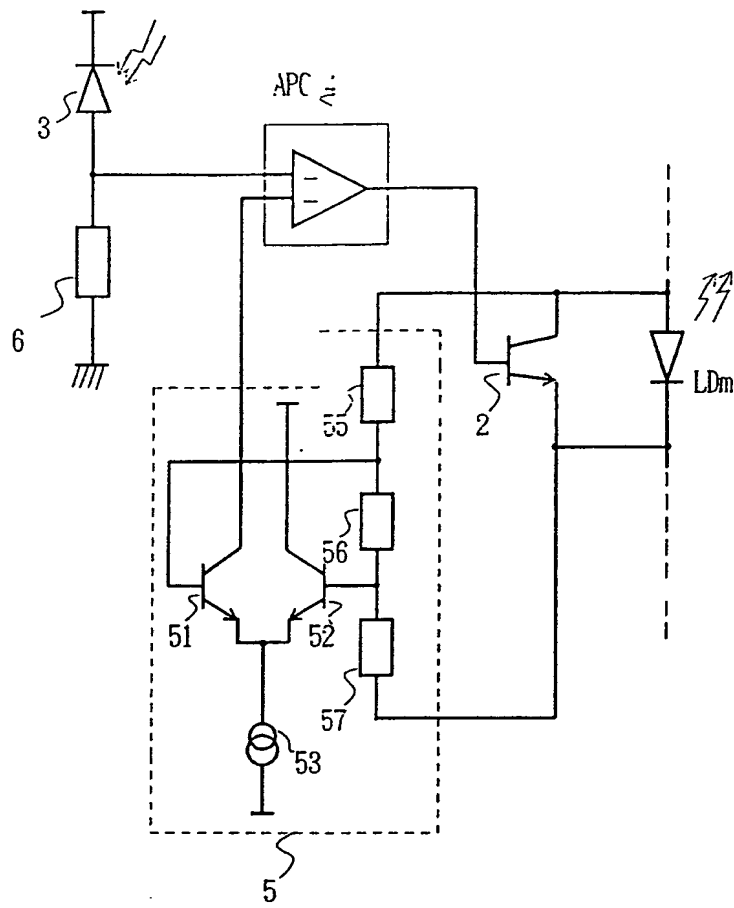
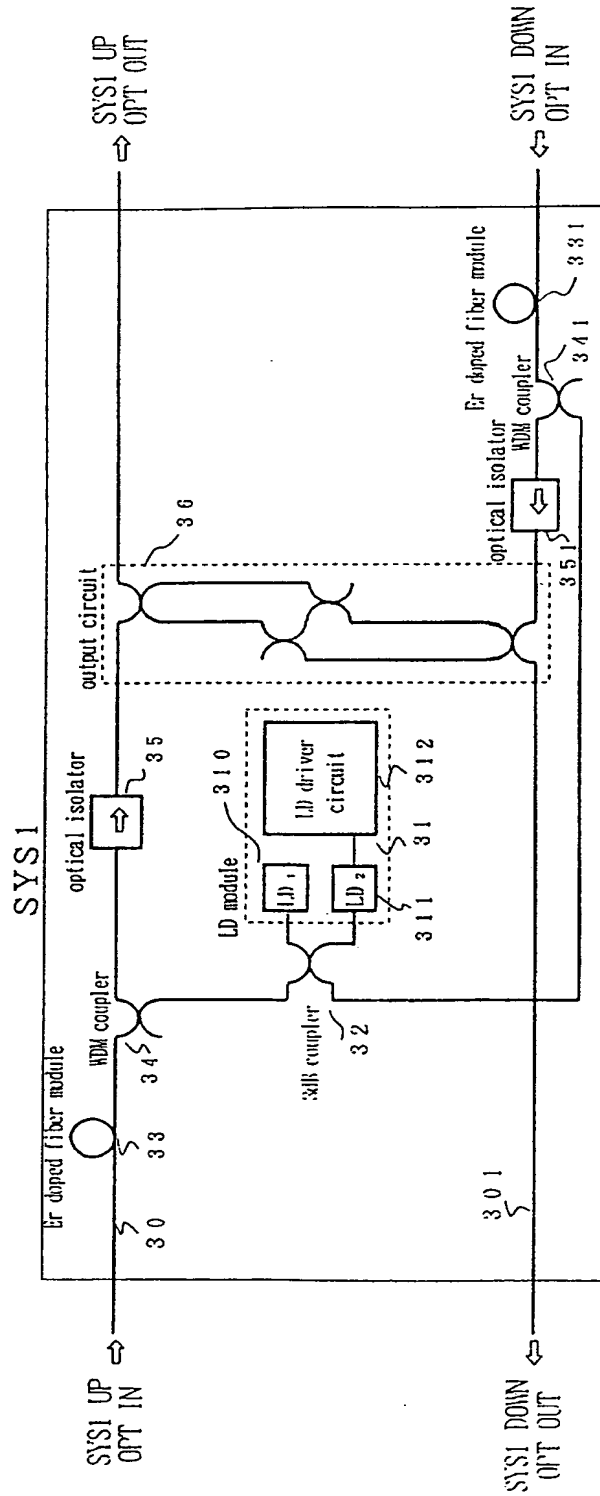


FIG. 3



4/7

FIG. 4



6/7

FIG. 5

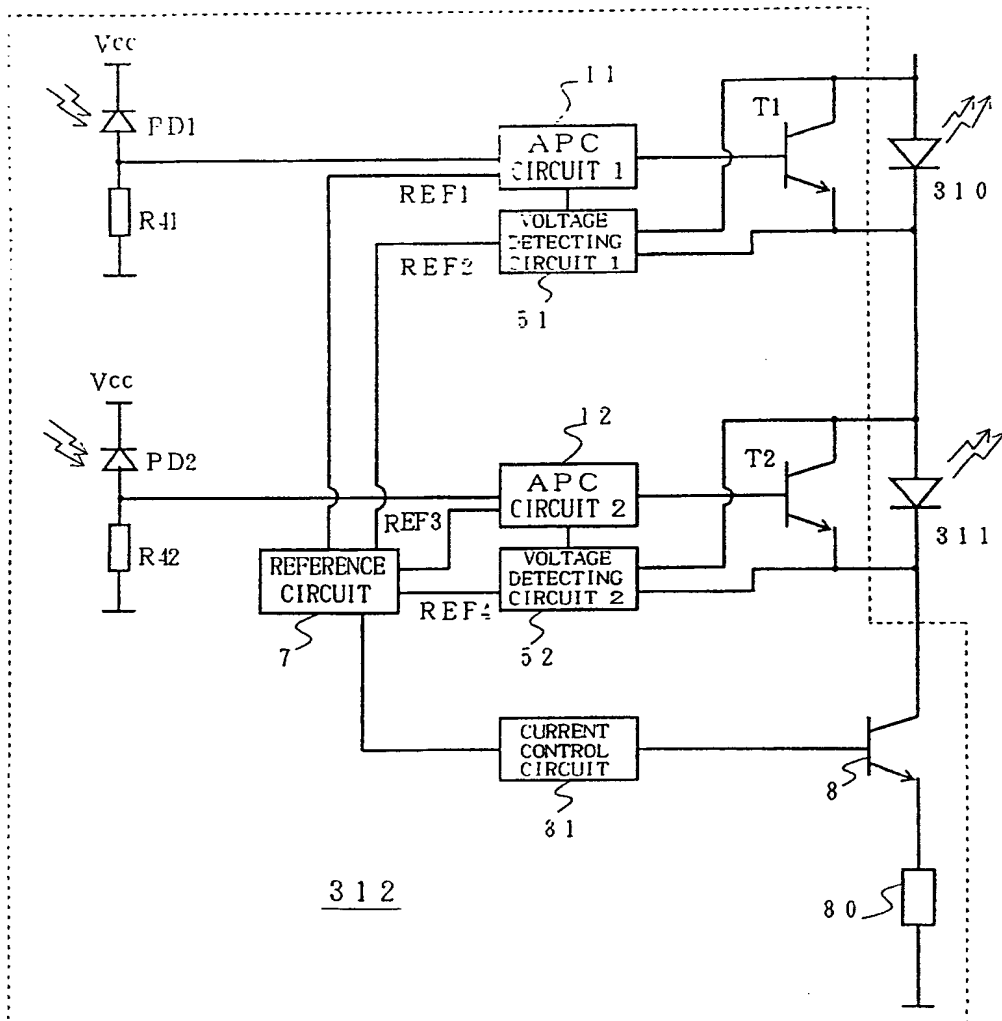
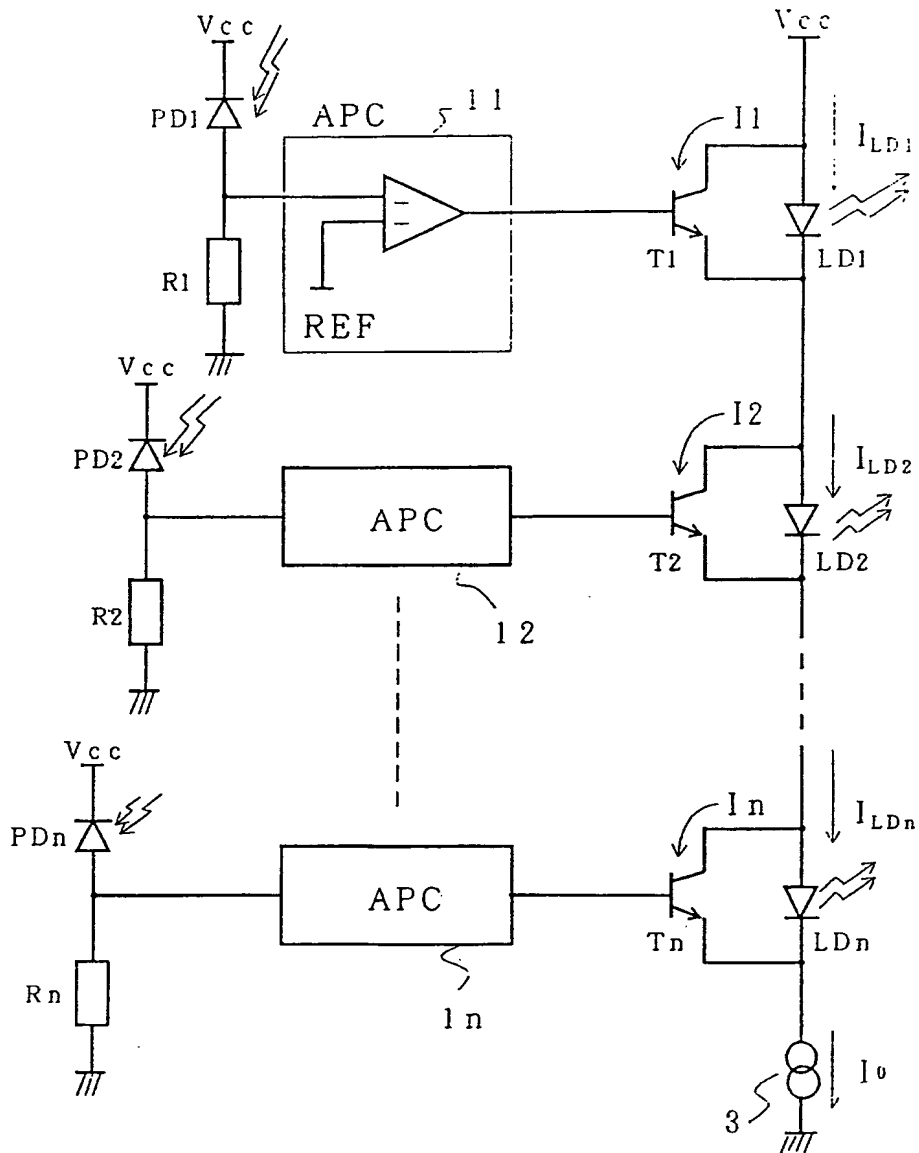


FIG. 6

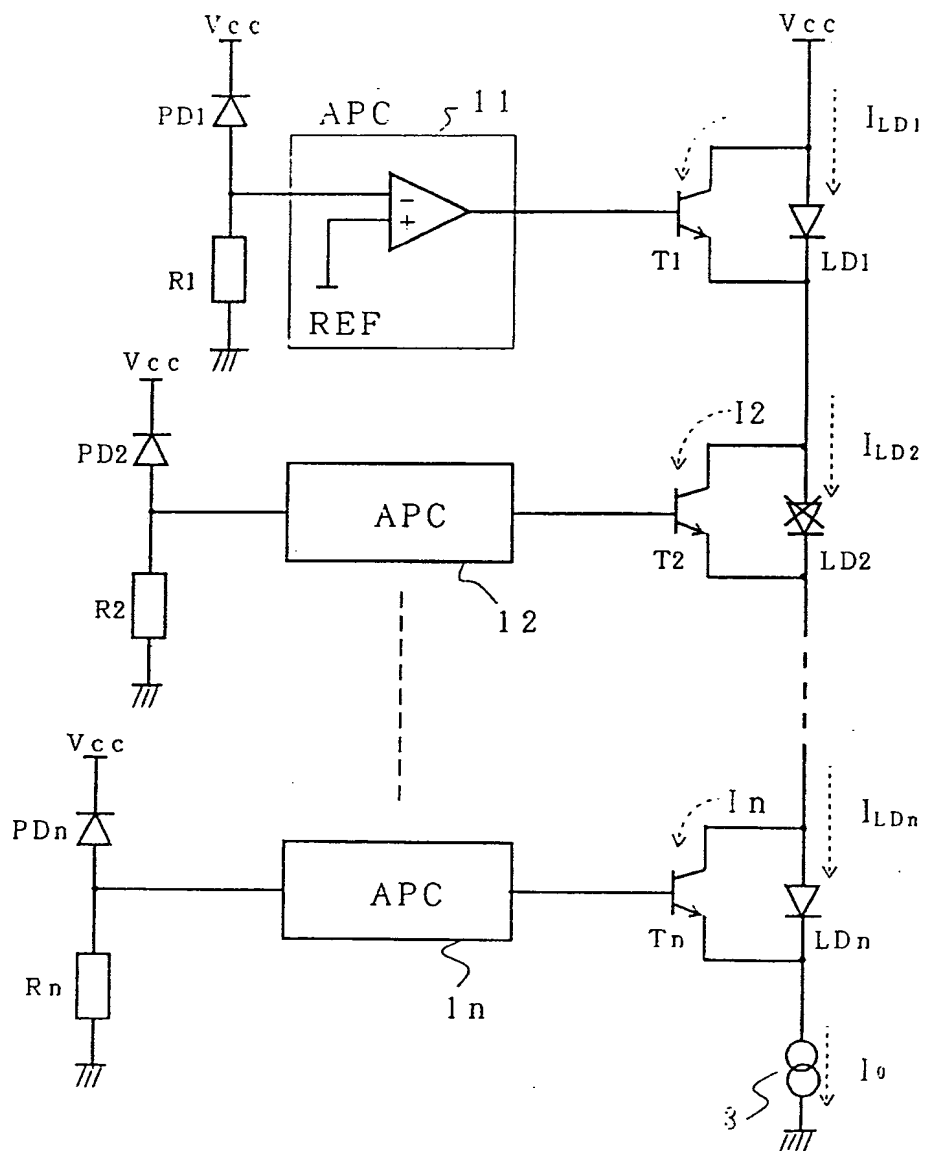
PRIOR ART



7/7

FIG. 7

PRIOR ART



5

OPTICAL DRIVER CIRCUIT

10

The present invention relates to a driver circuit for light emitting elements connected in series and an optical amplifying repeater using this circuit. More particularly, it relates to a driver circuit used in a light emitting source, which outputs composite optical power of lights emitted from plural light emitting elements.

20

Fig. 6 is a diagram for explaining a conventional circuit. In the diagram a series circuit of multiple light emitting elements, being laser diodes LD_1, LD_2, \dots, LD_n and a constant current power source 3 in series, is connected to a power source V_{cc} .

25

PD_1, PD_2, \dots, PD_n are light receiving elements, each of which detects optical power emitted from the corresponding light emitting element. More precisely they are photo

diodes.

These photo diodes are connected in series to resistors R_1, R_2, \dots, R_n , respectively and further connected to the power source V_{cc} .

5 Reference numerals "11, 12 ...1n" are optical power control circuits (APC), each having a first input terminal, which is supplied with the optical power level detected by the respectively corresponding light receiving element and a
10 potential REF.

T_1, T_2, \dots, T_n are bypass current control elements connected in parallel to light emitting elements LD_1, LD_2, \dots, LD_n , respectively. More precisely, they are transistors.

15 The outputs from the optical power control circuits 11, 12, ...1n as above-described, are inputted to the bases of the bypass current control elements T_1, T_2, \dots, T_n , respectively.

Each of the optical power control circuits 11, 12, ...1n
20 outputs a control signal having a voltage value which corresponds to that obtained by subtracting the light reception level detected by the light receiving elements PD_1, PD_2, \dots, PD_n from the corresponding reference voltage REF.

That is, when the light reception level becomes larger,
25 each of the optical power control circuits 11, 12...1n reduces the control signal input supplied to the base of the bypass current control elements T_1, T_2, \dots, T_n . A negative

feed back is given to the optical power of the light emitting elements.

When the respective optical powers from the light emitting elements $LD_1, LD_2 \dots LD_n$ increases, the
5 respective outputs of the optical power control circuits
11, 12...1n control to increase the electric currents $I_1, I_2, \dots I_n$ flowing to the bypass electric current elements $T_1, T_2, \dots T_n$, respectively and to decrease the electric currents $ILD_1, ILD_2 \dots ILD_n$ flowing to the light emitting
10 elements $LD_1, LD_2 \dots LD_n$, respectively and the optical power therefrom.

Contrarily, when the respective optical power from the light emitting elements $LD_1, LD_2 \dots LD_n$ decreases the
respective outputs of the optical power control circuits 11,
15 12,...1n control to decrease the currents flowing through the bypass electric current elements $T_1, T_2, \dots T_n$, respectively, and to increase the currents flowing through the light emitting elements $LD_1, LD_2 \dots LD_n$ respectively and the optical power therefrom.

20 Using such a structure, the optical powers from the light emitting elements $LD_1, LD_2 \dots LD_n$ are controlled so as to be constant.

In the above-described structure, for example, in the case where the light emitting element LD_2 deteriorates
25 some problems occur as follows.

Fig. 7 illustrates a diagram for explaining these problems.

In Fig. 7, let us now consider the case where the optical power of the light emitting element LD_2 becomes to zero because of a disconnection fault.

In such a case when the optical power from the light emitting element becomes smaller, each of the optical power control circuits 11, 12 ... 1n performs the control so as to make the base input of the corresponding bypass current control elements T_1, T_2, \dots, T_n smaller and make the electric current flowing through the light emitting elements $LD_1, LD_2 \dots LD_n$ larger.

Accordingly, the output from the corresponding optical power control circuit 12 controls so as to make the electric current flowing through the bypass current control element T_2 tend to zero and to make the electric current flow only through the light emitting element LD_2 , when the optical power of the light emitting element LD_2 becomes zero because of the disconnection fault.

However, in this case, no electric current through the light emitting element LD_2 flows because of the light emitting element LD_2 being disconnected. At the same time, the electric current does not flow in the series circuit of other light emitting elements $LD_1, LD_2 \dots LD_n$ and the constant current power source 3, as the electric current flowing through the bypass current control element T_2 is also controlled so as to be zero by the output of the optical power control circuit 12.

As above described, in the conventional circuit,

when any of the light-emitting elements $LD_1, LD_2 \dots LD_n$ meets with a disconnection fault, the currents of the corresponding bypass circuit control elements $T_1, T_2, \dots T_n$ are also controlled so as to be zero by virtue of the control of the optical power control circuits 11, 12, $\dots 1n$. Hence when any one of the light-emitting elements $LD_1, LD_2 \dots LD_n$ cannot output any optical power because of disconnection as above, no optical power can be obtained from the other still operational light-emitting elements.

Accordingly, it is an object of the present invention to provide a driving circuit for light-emitting elements to solve the problem of the conventional circuit.

It is a further object of the present invention to provide an optical amplifying repeater using a driving circuit for light-emitting elements to solve the problem of the conventional circuit.

The driver circuit accordingly to the present invention comprises:

a series circuit of a constant-current power source and multiple light-emitting elements, which are connected in series; and multiple optical power control circuits corresponding to each of the multiple light-emitting elements for controlling the optical power, each multiple optical power control circuit having a bypass current control element, which is connected in parallel to the corresponding light-emitting element, a light receptor element for detecting the optical power

of the corresponding light-emitting element connected to the bypass current control element, a current control circuit (APC) for controlling the current flowing to the bypass current control element in accordance with the light reception level of the light-emitting element, and a voltage detecting circuit for controlling the current control circuit so as to increase the current flowing to the bypass current control element when the voltage value between the terminals of the corresponding light-emitting element is detected and the detected voltage value becomes greater than a given voltage.

The invention can be applied to an optical repeater using control circuits as described above.

For a better understanding of the invention and to show how the same may be carried into effect, reference will now be made, purely by way of example, to the accompanying drawings in which

Fig. 1 is a circuit showing a first embodiment of the present invention;

Fig. 2 is a diagram showing one example of the current control circuit (APC circuit) in Fig. 1;

Fig. 3 is a circuit showing a second embodiment of the present invention;

Fig. 4 is a block diagram showing one embodiment in the case where the present invention is applied to an optical amplifying repeater;

Fig. 5 is a block diagram showing one embodiment of

the light emitting source for the optical amplifying repeater:

Fig. 6 is an explanatory diagram of a conventional circuit (No. 1); and

Fig. 7 is an explanatory diagram of the conventional
5 circuit (No. 2).

Fig. 1 is a first embodiment according to the present
10 invention. In the following explanation, same or like reference numerals are given to components which are identical or similar.

In Fig. 1, LD_m shows the m th light emitting element represented from multiple light emitting elements
15 LD_1, LD_2, \dots, LD_n .

Although the reference numeral 1 is the optical power control circuit for controlling this light emitting element LD_m , an optical power control circuit 1 is provided to correspond for each multiple light emitting element
20 having the same structure.

The numeral 2 is a bypass current control element, or more precisely it is a transistor having the collector and emitter connected to the light emitting element LD_m in parallel. "3" is a light receipt element, for example a
25 photo diode for detecting the optical power emitted from the light emitting element LD_m .

"6" means a load resistance element connected to the

light receiving element 3. Accordingly, when the light
receiving element 3 receives the optical power from the light
emitting element LD_m, the electric current corresponding
to the light reception level flows and a voltage potential is
5 presented at the connecting point of the load resistance
element 6 and the light receiving element 3.

"4" is a current control circuit (APC) 4 for
controlling the current flowing through the bypass current
control element 2 corresponding the light reception level of
10 the light receiving element 3 in the conventional circuit.

This current control circuit - has two input terminals.

The voltage potential of the connecting point between the
light receiving element 3 and the load resistance element 6
are connected to the first input terminal (-). On the other
15 hand, the output from the voltage detecting circuit 5
provided according to the present invention is connected on
the second input terminal (+).

In this voltage detecting circuit 5, the reference
numerals 51 and 52 are a pair of transistors having the
20 emitters commonly connected to the constant current power
source 53 and performing a differential operation. The
collector of the first transistor 51 of this pair of the
transistors 51 and 52 is connected to the second input
terminal (+) of said current control circuit 4 as the output
25 of the voltage detecting circuit 5.

The connecting point of the series circuit of a resistor
55 and a constant current power source 54 is connected to

the base of the first transistor 51. On the other hand, the connecting point of resistors 56 and 57 is connected to the base of the second transistor 52.

These resistors 56 and 57 are connected in series, and
5 both ends of the series resistors are supplied with the voltage potential between the collector and emitter of the bypass current control element 2, that is, the voltage potential of both ends of the light emitting element LD_m.

10 The operation of a circuit of the first embodiment according to the present invention which has the above-described structure is described as follows.

The light receiving element 3 detects the optical power emitted from the light emitting element LD_m, and the
15 voltage potential corresponding to the detection level is input to the first input terminal of the current control circuit 4. Further, the collector output of the first transistor 51 in the voltage detecting circuit 5 is input to the second input terminal of the current
20 control circuit 4.

In normal operation, the electric current flowing through the light emitting element LD_m is constant. Accordingly, the voltage potential between both terminals of the element is also constant, so that the
25 voltage potential at the connecting point of the resistances 56 and 57, that is, the base voltage potential of the second transistor 52 is constant, too.

Then, the values of resistors 55, 56 and 57 are set so that the electric current of the collector of the transistor 52 is equal to that of the constant current power source 53, and the electric current of the collector of the second 5 transistor 51, which forms a differential pair, becomes zero.

Accordingly, the current control circuit (APC) 4 outputs the output current which is in proportion to the electric current corresponding to the light level received 10 by the light receipt element 3 based on the constant bias current, which is decided by a reference output for setting a constant current value from a reference circuit, not shown in Fig. 1.

This output current is input to the base of the 15 bypass current control element 2 and controls the electric current of the collector. Accordingly, the electric current which flows to the light emitting element LD_m becomes constant, thus making the optical power constant.

On the other hand, let us consider the case where 20 the light emitting element causes a disconnection fault and the like, so that the optical power from the element becomes zero.

In the case where the light emitting element LD_m has a disconnection fault, electric current cannot flow, 25 and the voltage between the terminals of the element increases. Then, the voltage potential between the resistors 56 and 57 of the voltage detecting circuit 5

increases thus causing the voltage of the connecting point of the resistors 56 and 57, that is the base voltage potential of the second transistor 52 of ^{the} pair of the transistors, to be lower.

5 Accordingly, the electric current flowing through the transistor 52 is reduced. In contrast, the first transistor 51 is switched from the state of OFF to the state of ON, and the desired collector current I_c flows. This collector current I_c is brought to the second input
10 terminal of the current control circuit 4.

 Further, the base current of the bypass current control element 2 is made larger by the output of the current control circuit 4 corresponding to this collector current I_c .

15 As is apparent from the above-described structure, the optical power from other light emitting elements can continue to be obtained, because current supply to the other light emitting elements is performed by using the bypass current control element 2, even if it is a case where one
20 emitting element, for example, LD_n has a disconnection fault.

 Fig. 2 is one example of the current control circuit (APC) 4.

 Reference numerals "41" and "42" are a pair of
25 transistors for performing a differential operation and the constant current power source I_2 is connected to the commonly connected emitters. Further, the constant current

power sources I1 and I3 are connected to each of the bases.

The base of the transistor 41 becomes a first input (-) of the current control circuit 4. Accordingly, as described in Fig. 1, the base is connected to the connecting point of the light receiving element 3 and the load resistor 6, and the current corresponding to the light received by the lightreceiving element 3 is input to the base.

Both collectors of the transistors 41 and 42 are connected to the bases of the transistors 43 and 44, respectively. The commonly connected emitters of the transistors 43 and 44 are connected to the constant current power source I4. Further, both collectors of the transistors 43 and 44 are connected to the transistors 100 and 101, respectively.

The base of the transistor 101 is connected in common with the base of the transistor 102, the collector of which is connected to the base of the the transistor 45.

The collector of the transistor 44 becomes the second input terminal (+) of the voltage detecting circuit 5 shown in Fig. 1 and is connected to the collector of the transistor 101 at the same time. The emitter of the transistor 45 is connected to the base of bypass current control element 2.

Further, in Fig. 2, R1 ~R10 are resistors. The constant current power source Ii consists of the transistor 46 and the resistor R10. The base voltage potential of the transistor 47 of the series circuit of the

transistors 47 and 48 and resistors R8 and R9 is connected to the common base/collector of the transistor 46.

The base of the transistor 45 is given the reference voltage potential from the reference circuit not shown in the diagram, and the voltage potential of the collectors of the transistor 47 and the transistor 46 is set to a fixed constant voltage potential. Thus, the electric current flowing through the transistor 46 is set to a fixed constant.

10 The constant current power sources I2 through I4 have the same structure as the constant current power source I1, and are connected in common with the collector of the transistor 47 which is not shown in the diagram. Further, the constant current power sources 53 and 54 of the voltage
15 detecting circuit 5 in Fig. 1 also have the same structure as the constant current power source I1, and are given the reference voltage potential from said reference circuit.

In the above-described structure, the operation of the current control circuit 4 described in Fig. 1 is performed.
20 That is, the emitter voltage potential of the transistor 45 becomes the fixed voltage potential in the normal condition, and the constant value of each element and the current of the constant current power sources I1 through I4 are set so as to turn the bypass control element 2 to the
25 state of OFF, i.e. to make a large part of current flow through the laser diode LD_m connected in parallel.

On the other hand, in the case where the laser diode

LD_m has a disconnection fault, the collector of the transistor 44 reaches a high potential and accordingly, the base of the transistor 45 has high potential. too, as the collector current I_c of the transistor 51 (referring to Fig. 1) is
5 drawn to the voltage detecting circuit 5.

Then, the transistor 45 becomes conductive, so that the base electric current of the bypass electric control element 2 becomes larger and it becomes possible to supply the electric current to other laser diodes LD connected in
10 series even in the case where the laser diode LD_m causes a disconnection fault.

Fig. 3 illustrates a circuit for explaining the second embodiment of the present invention and the structure of the voltage detecting circuit 5 is made simple, compared with
15 the embodiment in Fig. 1. The other structures are the same as the circuit of the embodiment in Fig. 1.

That is, the voltage detecting circuit 5 in the embodiment of Fig. 3 is constituted from the series circuit of a pair of the transistors 51 and 52, the resistors 55
20 through 57 and the constant current power source 53.

Both ends of the series circuit of resistors 55 through 57 are connected to both terminals of the light emitting element LD_m. Further, each base of the transistors 51 and 52 is respectively given the voltage potential of each
25 terminal of the resistor 56. Furthermore, the collector of the transistor 51 is connected to the second input terminal of the current control circuit 4.

In the case where the light emitting element LD_m is in the condition of normal operation, this structure is the same as the one described in Fig. 1. Further, the operation in the case where the light emitting element LD_m causes
5 disconnection fault, so that the optical power becomes zero as follows.

The voltage potential between both terminals increases owing to the disconnection of laser diode LD_m, which is the light emitting element. And then, the base voltage
10 potential of the transistor 52 decreases while the base voltage potential of the transistor 51 increases.

Accordingly, the OFF state of the transistor 51 when the light emitting element LD_m is in the condition of normal operation is switched to the ON state and the
15 collector current I_c of the transistor 51 flows to the current control circuit 4. Thus, as described in Figs. 1 and 2, the bypass current control element 2 becomes conductive, thus keeping the supply of the electric current to other light emitting elements LD.

20 Fig. 4 is a block diagram showing one embodiment in the case where the present invention is applied to an optical amplifying repeater. Further, it is a structural block diagram of the optical amplifying repeater according to SYS 1 of duplicate system (SYS 1, SYS 2) for work and protect.

25 In the diagram, 30 and 301 are optical transmission lines in the ascending channel and descending channel. Each of the optical transmission lines in the ascending

circuit 30 and the descending channel 301 is provided with
Er doped fiber modules 33 and 331, WDM couplers 34 and
341 and optical isolators 35 and 351.

Further, an output circuit module 36 is provided
5 between the optical transmission lines 30, 301 in the
ascending and the descending channels for performing
loop-back communication.

The Er doped fiber modules 33 and 331 are optical
repeaters constituted by the wound optical fiber of the
10 several meters ~ several 10 meters, doped with erbium (Er),
which is a rare earth element.

This optical repeater is used for performing an
amplification function by using the characteristic that
inducted emission is produced and the power of signal light
15 becomes larger gradually along the optical fiber, in the
case where the signal light is input to the Er atoms in
the optical fiber, excited to a higher energy level by the
exciting light (for example, the wave length of $1.48 \mu\text{m}$).

"31" means the light exciting source using the driving
20 circuit of the light emitting element according to the
present example for supplying the exciting light for the
Er doped fiber modules 33 and 331. It has a first laser
diode 310, a second laser diode 311 and the driving circuit
312.

25 The optical power of two laser diodes 310 and 311 is
composed by the 3 dB coupler 32, branched, and supplied to
the Er doped fiber modules 33 and 331 coupled to the fiber

transmission lines 30 and 301 by the WDM couplers 34 and 341 for the ascending and descending channels.

The light exciting source 31 using the driving circuit for the light emitting element according to the present example is constituted as shown in Fig. 5 as an embodiment.

In Fig. 5, the light receiving elements PD1 and PD2 are provided corresponding to the two laser diodes 310 and 311.

The light reception current of these light receiving elements PD1 and PD2 is inputted to the current control circuits (APC circuits) 11 and 12, which have the same structure and function as the current control circuit 4 described in Figs. 1 and 2.

On the other hand, 51 and 52 are the voltage detecting circuits, which have the same structure and function as the voltage detecting circuit 5 described in Figs. 1 and 3. Thus, it is a circuit for performing control by the current control circuits (APC circuits) 11 and 12 depending on the output, when disconnection (open) of the laser diodes 310 and 311 are detected, so as to increase the base current of the bypass current control elements T1 and T2.

Accordingly, returning to Fig. 4, the light output from the 3dB coupler 32 decreases by half, but does not become zero, because of the light exciting source 31 in Fig. 5, which includes the driving circuit of the light emitting element according to the present invention, even if it is the case where ^adisconnection fault occurs on either of two

laser diodes 310 and 311 .

Hereby, it becomes possible to retain the excitation light of the Er doped fiber modules 33 and 331. That is, by applying the present invention, reliability of the system
5 increases as the optical amplifying repeater continues to work, even in the case where ^adisconnection fault occurs on the laser diodes 310 and 311.

According to the present invention, it becomes possible
10 to maintain the supply of bias electric current to other light emitting elements, even if ^adisconnection fault of one light emitting element occurs in the circuit having multiple light emitting elements connected in series. Accordingly, it becomes possible to keep the optical power emitted from
15 multiple light emitting elements.

More particularly, it become possible to maintain the reliability of the system in the case where the driving circuit for the light emitting elements according to the present invention is used as the optical power source on the
20 optical transmission system.

Claims:

1. A driver circuit for light-emitting elements connected in series so as to form a series circuit of a constant current power source (I) and multiple light-emitting elements ($LD_1 \sim LD_n$), which are connected in series; the driver circuit including multiple optical power control circuits (1), corresponding to the multiple light-emitting elements ($LD_1 \sim LD_n$), for controlling the optical power of the light-emitting elements; each optical power control circuit (1) having:

a bypass current control element (2), which is connected in parallel to the corresponding light-emitting element ($LD_1 \sim LD_n$),

15 a light receptor element (3) for detecting the optical power of the corresponding light-emitting element;

a current-control circuit (APC) (4) for controlling the current flowing to the bypass current control element (2) in accordance with the light reception level of the light receptor element (3), and

a voltage-detecting circuit (5) for controlling the current-control circuit (4) so as to increase the current flowing to the bypass current control element (2) when the voltage value between the terminals of the corresponding light-emitting element (LD_m) is detected and the detected voltage value becomes larger than a

predetermined voltage value.

2. A driver circuit according to claim 1,
wherein the light-emitting elements ($LD_1 \sim LD_n$) are
laser diodes and the receptor elements (3) are
5 photodiodes.

3. A driver circuit according to claim 1 or
claim 2, wherein the bypass current control element (2)
comprises a transistor, the corresponding light-
emitting element is connected in parallel between the
10 collector and the emitter of the transistor, and the
base current of the transistor is controlled by the
current control circuit (4).

4. A driver circuit according to claim 1, 2 or
3, wherein the current control circuit (4) includes a
15 differential amplifier having a first input terminal
and a second input terminal, the first input terminal
is supplied with a voltage potential corresponding to
the light power received by the light receptor element
(3), the second terminal is supplied with the output of
20 the voltage-detecting circuit (5), and the differential
amplifier supplies an output corresponding to the
difference between the input of the second input
terminal and the input of the first input terminal to
the bypass current control element (2).

25 5. A driver circuit according to claim 4,
wherein the voltage-detecting circuit (5) has a pair of
transistors (51, 52), the emitters of which are

commonly connected to a constant-current power source,
a reference potential is applied to the base of one
transistor (51) and the collector of the first
transistor is connected to the second input terminal of
5 the differential amplifier in the current control
circuit (4), and a voltage potential proportional to
the voltage between the terminals of the light-emitting
elements is applied to the base of the second
transistor (52).

10 6. A driver circuit according to claim 4,
wherein the voltage-detecting circuit (5) has a pair of
transistors (51, 52), the emitters of which are
commonly connected to a constant-current power source,
the collector of the first transistor (51) is connected
15 to the second input terminal of the differential
amplifier of the current control circuit (4), and
voltage potentials proportional to the voltage between
the terminals of the light-emitting element are applied
to the bases of the first and second transistors (51,
20 52).

7. An optical amplifying repeater having optical
transmission fibres (30, 301), fibre modules (33, 331)
positioned in the path of the optical transmission
fibres (30, 301) and an excitation light source (31)
25 for supplying excitation light to the fibre modules
(33, 331),

wherein the excitation light source (31) includes

a series circuit of a constant-current power source (I) and multiple light-emitting elements, which are connected in series; and a driver circuit as claimed in any preceding claim.

- 5 8. An optical amplifying repeater having optical transmission fibers (30, 301) for ascending and descending channels, first and second Er-doped fiber modules (33, 331), which are positioned on each of the optical transmission fibers (30, 301) for the ascending
10 and descending channels, respectively,

an excitation light source (31) for supplying an excitation light to the first and second Er-doped fiber modules (33, 331),

- a coupler (32) for branching the excitation light
15 from the excitation light source (31), and

first and second WDM couplers (34, 341) for uniting the excitation light branched from the coupler (32) to the optical transmission fibers (30, 301) on the ascending and descending channels,

- 20 wherein the excitation light source (31) includes a series circuit of a constant-current power source (I) and multiple light-emitting elements ($LD_1 \sim LD_n$), which are connected in series; and a driver circuit according to any of claims 1 to 7.

- 25 9. A repeater according to claim 7 or 8, in which the fiber modules are Er-doped and which includes means for supplying the Er-doped modules (33, 331) by

composing optical power from the light-emitting elements ($LD_1 \sim LD_n$).

10. A driver circuit substantially as described with reference to any of Figures 1 to 3.

5 11. An optical repeater substantially as described with reference to Figures 4 and 5.

Patents Act 1977
Examiner's report to the Comptroller under Section 17
(The Search report)

24.

Application number
GB 9410561.6

Relevant Technical Fields

(i) UK Cl (Ed.M) HIC (CBAA, CBAX, CEA, CEX); GBR (RBX)

(ii) Int Cl (Ed.5) H01S 3/09, 3/091, 3/0933, 3/094

Databases (see below)

(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii)

Search Examiner
B MOBBS

Date of completion of Search
13 JULY 1994

Documents considered relevant
following a search in respect of
Claims :-
1-11

Categories of documents

- | | |
|--|---|
| <p>X: Document indicating lack of novelty or of inventive step.</p> <p>Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.</p> <p>A: Document indicating technological background and/or state of the art.</p> | <p>P: Document published on or after the declared priority date but before the filing date of the present application.</p> <p>E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.</p> <p>&: Member of the same patent family; corresponding document.</p> |
|--|---|

Category	Identity of document and relevant passages	Relevant to claim(s)
A	GB 2245757 A (KOKUSAI DENSHIN DENWA)	

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☒ FADED TEXT OR DRAWING
- ☐ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☐ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☐ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☒ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.